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# Alternatives To Cadmium Plated Military Connectors

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# Outline

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- Connector types
- Desirable properties of Cadmium
- Alternate finish reports and connector industry test data
- Other possible non cad alternatives
- Recommendations

# Cadmium plated connectors

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- The military and aerospace industries have used cadmium plating for aluminum and stainless steel connectors for over 60 years. Recent pressure from DOD, US dept of labor, RoHS and REACH policy all intend to restrict, control exposure or ban use of this material. Cadmium is coated with a chromate finish which is also hazardous. Chromate colors used on connectors are olive drab, black and yellow.

# Cadmium connector specifications

- DLA and SAE have changed nearly every connector specification and slash sheet to add alternate finishes to cadmium.
  - Mil-DTL-38999 and associated slash sheets and MS sheets
  - MIL-PRF-28840 and associated slash sheets
  - MIL-DTL-26482 and associated MS sheets
  - MIL-DTL-83723 and associated slash sheets
  - MIL-DTL-22992 and associated MS sheets
  - MIL-PRF-83513 and associated slash sheets
  - MIL-PRF-24308 and associated slash sheets
  - MIL-DTL-83733 and associated slash sheets
  - Mil-PRF-28876
  - Mil-PRF-83513
- SAE AS85049 is changed and at the majority of over 100 slash sheets are complete.
- SAE AS50151 is scheduled for update to add alt finishes in 2011.
- Problem. No qualified sources available for most connector specs except for 38999, 26482 and 83513

**Connector mfr's need to qualify their alt finishes**

## Desirable properties of Cadmium

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- Cadmium can be electroplated relatively thin (200-800 microinches) and evenly on fine and coarse threads and complex geometries. Nickel underplate is typically used to increase wear and corrosion resistance.
- Thread lubricity (500 mating cycles min)
- Can meet coupling and uncoupling torque after exposure to severe corrosion environments.
- Corrosion resistance (500-1000 hrs min neutral salt spray). Able to pass dynamic salt spray test requires 50 mating cycles prior to salt spray test, followed by remaining 452 mating cycles, check mating torque and shell to shell conductivity.
- Conductivity for EMI shielding, electrical bonding and lightning strike (2.5 milliohms max shell to shell resistance)

# Desirable properties of Cadmium

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- Non reflective finish
- Finish can be marked with color bands for full mate indicator, military P/N and date code, supplier mark. Marking remains permanent after normal use and exposure to solvents.
- Galvanic compatibility with cable shield materials (tin, silver and nickel), stainless steel coupling nut retaining rings, cable shield bands, EMI spring fingers, EMI shielding gaskets and aluminum mounting panels.
- Resistance to solvents.
- Compatible with hermetic connectors with fused tin on carbon steel.
- Works well with adhesives used to bond plastic inserts and silicone grommets used in connectors.
- Meets vibration, shock, humidity, EMI shielding, bending moment and other connector performance requirements.

# SAE AE8-C1 connector committee recommended alternate finishes

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- There are 3 alternate military connector finishes that can be considered to replace cadmium plating on aluminum.
  - Nickel-Fluorocarbon
  - Zinc-Nickel
  - Pure Dense Aluminum
- Zinc-Nickel and Aluminum currently contain hexavalent chromate. Nickel-Fluorocarbon requires no supplementary chromate. Aluminum plating is inherently soft and requires a thread lubricant.



# SAE AIR5919A Alternate Finishes report

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- This SAE aerospace information report AIR5919 was updated in July 2010 to provide alternate finish test data summary from 7 suppliers who tested their alt finishes on connectors and accessories. Some alt finishes were mated to cadmium plated aluminum for galvanic compatibility after environmental testing for neutral (500-1000 hrs) and acidic (SO<sub>2</sub>, 336 hrs) salt spray corrosion tests after 500 mating cycles. Shell to shell conductivity and coupling torque performance was also measured before and after environmental testing.

# SAE AIR5919A

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- Nickel-Fluorocarbon finish performed the best overall but is still not considered a drop in replacement for cadmium. Other finishes tested were Zinc-nickel, Electrodeposited Aluminum, IVD aluminum, Zinc-Cobalt and Cadmium control samples. Most of the data is on parts with aluminum base metal but SST and Composite bodies is also reported.
- Cadmium finish when mated to Zinc-Nickel and Aluminum plating did not perform very well. Some plating recipes performed poorly.

## Other alt finish reports

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- Joint Strike Fighter report by Lockheed Martin.
- Saab Bofors Dynamics report
- NDC EE/TARDEC report
- Radial report from Feb 2011 Assets Defense conference
- Amphenol Aerospace Operations report.

# Chromate finish

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- Hexavalent chrome was targeted by DOD for prohibition on new system designs. DFARS Case 2009-D004 document was signed into law in 2011. Chemical film finishes were not prohibited due to lack of available drop in replacements, but this will change as alternatives become available.
- Trivalent chrome and other non-chrome alternatives are available for some paint primer applications but they are not drop in replacements for hex chrome.
- Color options very limited for non hex chrome alternates. Olive drab color is not available. Trivalent chromates colors are at present only available in tan or blue-ish . Marking permanency on non hex chrome alternates is unknown. The mil spec connector marking is required to meet a resistance to solvents qualification test which is harsh on marking.

## Ruggedized cylindrical fiber optic connectors

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- The fiber optic connector spec MIL-PRF-28876 is written to require sources to qualify an alt finish, but suppliers have been unsuccessful qualifying an alternate finish to cadmium. Navy round robin corrosion testing using several suppliers cad and alt finished parts went poorly resulting in loss of confidence in alt finishes. Report is not available for public release so it is unknown what alt finishes were tested.
- The NGConn spec MIL-PRF-64266 is the next generation fiber optic connector spec which has no qualified suppliers yet. Cadmium is prohibited in this spec. Commercial parts are available in zinc-nickel. Backward compatibility issue with cad.

# TTH (tradename ICORE) nickel-fluorocarbon backshell

## After 2000 hours salt spray

TTH plated accessory mated to an Electroless Nickel Plated Connector After 2000 hours salt fog exposure.



## Alternative connector finishes

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- 38999 series III, class L in nickel plated stainless steel is another alternate finish option that was recently qualified by Amphenol. There are no matching AS85049 backshells available yet in this material. There is a weight, availability and cost penalty for using stainless steel connectors.

# Alternative connector finishes

- Composite 38999 connectors (D38999 series III and IV, class J and M) are also available as an alternative to aluminum bodies. They are available in cadmium or nickel plating and soon may become qualified with the 3 alt finishes. These parts are good for severe corrosion applications and have up to a 2000 hour salt spray test rating, as compared to class W cadmium at 500 hrs min. These connectors are primarily used for weight sensitive airborne platforms.
- Composites do not meet direct lightning strike. Composite connectors have thin metal plating which can melt if subjected to high currents from direct lightning strike (150K-200K amps) or EMP from a nuclear event. 38999 spec specifies the indirect lightning strike capability which are at reduced amperages from an all-metal body connector. Shell sizes 9 and 11 should be avoided in direct strike locations.
- Composite connectors barely meet bending moment test requirements. They do not have the strength of metal body connectors that can sometimes be used as footsteps by serviceman to climb up onto military equipment.



## Alternative connector finishes

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- Jam nut mount composite receptacles cannot be used in electrical bonding applications due to thread relaxation of mounting nut over time. The shell to shell conductivity is slightly less than cadmium (3 milliohms max vs 2.5 for cad). Flange mount receptacles must be used in applications where electrical bonding for lightning and EMI shielding is required.
- Limited composite backshell accessories and qualified sources available in AS85049.

## Recommendations for further studies

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- Develop non-hex chromate finishes with non-reflective color
- Continue to seek and test alt finishes compatible with cadmium and other alt finishes.
- Galvanic compatibility of the cable assembly system must be considered to insure compatibility with cable shield materials, accessories and mounting panels. More galvanic testing is required to build confidence in the alt finishes. Connector finishes are in direct contact with tin, silver, nickel, stainless steel retaining rings, aluminum panels and various EMI shielding gasket materials (monel, metal particle filled elastomers). SAE AIR4789 and AIR5919 are suggested for test plans and inspection criteria.

## Recommendations for further studies

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- Nickel-Fluorocarbon appears to be the best performing finish on aluminum and is compatible with cadmium connectors in the existing equipment. Although the nickel and cadmium are shown as incompatible couples on the galvanic chart, the teflon component in the nickel provides inertness. The plating recipe can vary performance results. Connector manufacturers have to develop their own plating system and qualify connectors to the various connector specifications.
- SAE is in process of releasing a nickel-PTFE plating specification in 3<sup>rd</sup> qtr 2011.
- Alt finishes should be compatible with new solvents and Green de-icers. SAE in process of updating de-icers and cadmium has been shown to be incompatible.

# Conductive Green De-icer is corrosive to Cad

Cryotech E-36 De-Icer  
Standard OD Cad "W" finish  
Post 8 weeks of Immersion



Fails IR at 100 VDC - Fails Shell Conductivity

## Alt finish disadvantages

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- Aluminum plated finish is incompatible with tin and nickel cable shields or crimp rings.
- Aluminum finish soft and requires use of thread lubricant.
- Zinc-nickel not backward compatible with cad. Some testing on Zinc-nickel finish has shown siezed coupling nuts after salt spray, or unacceptable coupling/uncoupling torques,
- Zinc-cobalt only capable of 300 hrs salt spray.

## Misc info

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- Nickel mated to cad is OK for interior protected applications. Salt spray rating only 48 hrs for nickel plated aluminum.
- High frequency only a concern with EMI shielding. 60-80 db shielding effectiveness to 10 Ghz easily achieved with any conductive finish that is not degraded by environmental stress and corrosion. RF coaxial connectors don't use cadmium plated bodies.
- There are 2 suppliers qualified for alternate finishes in 38999, series III. Class Z (zinc-nickel) and class T (nickel-fluorocarbon) finishes. Souriau is qualified to supply Class Z and Amphenol is qualified to supply class T. Other connector and accessory specs that list alt finishes should have qualifies sources soon.